A Conceptual Model of the Galveston Bay Ecosystem

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The Galveston Bay National Estuary Program

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The Galveston Bay National Estuary Program

Texans increasingly express their expectations for a clean environment in terms of entire ecosystems. Until recently, our tendency was to view environmental problems in isolated pieces we could understand—indeed this view was institutionalized (and seemingly immortalized) in an elaborate mosaic of fragmented jurisdictions. The Galveston Bay National Estuary Program (GBNEP) is a forerunner in elevating hands-on management of coastal environments to the level of the ecosystem; and in doing so, is encouraging an integration of traditionally disparate institutions.

The GBNEP was established under the authority of the Water Quality Act of 1987 to develop a Comprehensive Conservation and Management Plan (CCMP) for Galveston Bay. The purpose of the CCMP is to address threats to the Bay resulting from pollution, development, and overuse. To address these threats, five years of work commenced in 1990, consisting of three phases: (1) Identification of the specific problems facing the Bay; (2) A Bay-wide effort to compile data and information to describe status, trends, and probable causes related to the identified problems; and (3) Creation of the CCMP itself to enhance governance of the Bay at the ecosystem level. The GBNEP is accomplishing this work through a cooperative agreement between the U.S. EPA (Region 6) and the State of Texas (administered by the Texas Natural Resource Conservation Commission.)

The structure of the GBNEP reflects a strong commitment to consensus-building among all Galveston Bay user groups, government agencies, and the public. The GBNEP "Management Conference" consists of six Governor-appointed committees with broad representation, totaling about one hundred individuals. Meetings of these committees are also open to the public, and public participation in policy-setting and in Bay management are considered strengths of the program. When submitted to the Governor of Texas in late 1994, the CCMP will reflect thousands of hours of involvement (much in the form of volunteer time) by individuals who in various ways use, enjoy, or help govern this vital coastal resource.

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PREFACE

The goal of this project was to achieve scientific consensus on some conceptual models of the Galveston Bay ecosystem. To achieve this end, the habitat models were developed and circulated to a large group of experts. The author then met with these scientists, singly and in groups, for lengthy discussions and critique of the models.

The following scientists provided invaluable comments on the habitat models during these discussions. Neal Armstrong and George Ward of the University of Texas Center for Research on Water Resources in Austin; Terry Whitledge and Edward Buskey of the University of Texas Marine Science Institutute in Port Aransas; Eric Powell of Texas A&M University at College Station; Cynthia Howard of the University of Houston - Clear Lake; Roger Zimmerman, Tom Minello and Peter Sheridan of the National Marine Fisheries Service Southeast Fisheries Center in Galveston; Bob Bass of the U.S. Army Corps of Engineers in Galveston; and Albert Green, Lynn Benefield and Larry McEachron of the Texas Parks and Wildlife Department in Austin, Seabrook and Rockport, respectively. Additional written or telephoned comments were provided by Sammy Ray, Andre Landry and Don Harper of Texas A&M University at Galveston; Frank Fisher of Rice University; James Lawrence of the University of Houston - University Park; David Flemer of the Environmental Protection Agency Gulf Breeze Laboratory; and Will Roach, Tom Czapla and Fred Werner of the U.S. Fish and Wildlife Service - Houston.

The detailed habitat models were revised to accommodate the review comments and scientific consensus regarding the habitat-based conceptual models was thus achieved. The simple, non-technical overview models were then constructed, focusing on the theme that distant events anywhere in the watershed could potentially affect the bay ecosystem. The issue of perturbations and their management was taken to the GBNEP Scientific/Technical Advisory Committee (S/TAC) which achieved consensus regarding the sources of perturbation and the physical, chemical and biological perturbations expected to occur. The following members of the S/TAC provided evaluations regarding the influence, scientific credibility, and manageability of these perturbations. Jerry Wermund of the University of Texas Bureau of Economic Geology; Ernst Davis of the University of Texas School of Public Health - Houston; James Lawrence of the University of Houston - University Park Department of Geosciences; Bruce Smith of the Texas General Land Office; Gary Powell of the Texas Water Development Board; Albert Green of the Texas Parks and Wildlife Department Resource Protection Division; Will Roach of the U.S. Fish and Wildlife Service; Rick Medina of the U.S. Army Corps of Engineers - Galveston; Dick Brown of the Gulf Coast Waste Disposal Authority; and Joe Kolb of the Enron Corporation.

The complete draft of the models was then distributed to the scientific advisors, the GBNEP review panel, and additional reviewers. Written comments were submitted by Neal Armstrong of the University of Texas; Terry Whitledge of the University of Texas Marine Science Institute; Eric Powell and an anonymous reviewer at Texas A&M University - College Station; James Lawrence of the University of Houston - University Park (GBNEP Designated Reviewer); Roger Zimmerman and an anonymous reviewer of the National Marine Fisheries Service; David Flemer and Ken Teague of the Environmental Protection Agency; Gary Powell of the Texas Water Development Board; Tom Calnan of the Texas General Land Office; Tracey Koenig and Keith Kindle of Turner, Collie and Braden, Inc.; Glenda Calloway of Ekistics Corporation; and Sandra Hoover of the GBNEP Citizens Advisory Steering Committee.

The success of these models is due to the unstinting willingness of these reviewers to devote large chunks of their busy lives to my estuarine education. They called my attention to many obscure and unpublished reports, as well as commissions of error or misunderstanding. Although I have not always followed all of their advice and counsel, I am especially grateful for their unselfish sharing of their vast knowledge of the inner workings of estuaries. I alone am responsible for errors of fact or misunderstanding which remain in the models. Although I suspect that many of these scientists may still disagree on minor interpretations, particularly omissions, I am confident that the goal of scientific consensus has been achieved.

Robert W. McFarlane

A CONCEPTUAL MODEL OF THE GALVESTON BAY ECOSYSTEM

Robert W. McFarlane, Ph.D.
Principal Investigator

EXECUTIVE SUMMARY

The goal of this project was development of a set of habitat-based, problem-oriented, nested, hierarchical, box-and-arrow conceptual models tiered to three levels of complexity. (1) Simple, nontechnical models that facilitate understanding of important issues by the public focus on the landscape approach and provide an overview of the ecosystem. (2) Complex detailed models that reflect scientific consensus describe the structure, function and connectivity of the habitat components of the ecosystem and it s connections to adjacent habitats. (3) Simple technical models useful to decision-makers, resource managers and bay users describe the interconnectedness of the ecosystem.

The bay ecosystem can be greatly influenced by actions occurring far from the bay. It is dependent upon some distant actions, such as spawning of shrimp and finfish in the Gulf of Mexico or precipitation runoff in a remote portion of its watershed. It can be impaired by other actions, such as wastewater discharge and oil or chemical spills. Seven distinct habitats comprise the bay ecosystem: open-bay water, open-bay bottom, oyster reefs, seagrass meadows, peripheral mudflats, peripheral marshes, and peripheral marsh embayments. The physico-chemical conditions within these habitats vary spatially and temporally. The habitats are connected to adjacent riverine-floodplain and nearshore gulf ecosystems and distant portions of the continent. The dominant characteristic of the ecosystem is continual physical, chemical and biological change.

Each habitat component involves dozens of species linked together in complex food webs. Many organisms utilize more than one habitat, particularly those highest in the food chain. Both grazing and detrital food webs are prominent in the ecosystem. Nutrients enter from the riverine connections, are regenerated by the benthic microbial community, and are extracted from the atmosphere. The plankton-grazing food web supports the oyster harvest and contributes, via intermediaries, to the fish harvest. Detritus comes from the rivers and all component habitats. The detritivore food web supports the shrimp and blue crab harvest and contributes to the fish harvest.

Perturbations which affect the ecosystem have been identified but consensus regarding the influence of these perturbations on component habitats, the scientific reliability of opinions regarding these influences, and manageability of the perturbations was not achieved. The habitat approach may not be an effective way to evaluate perturbations.

I. INTRODUCTION

Estuaries such as Galveston Bay are complex and constantly changing ecosystems. To optimize management of the anthropogenic factors which affect the ecosystem, and to be able to predict the potential impact of a proposed action, it is necessary to understand how the system is structured and interacts with its environs. Knowledge of the structure of the ecosystem, and the diverse plants and animals which build and inhabit its distinct habitats, does not automatically lead to understanding of its functions. It is also important to understand how it acquires its materials and energy, processes its waste products, and interacts with adjacent waters and the surrounding landscape.

Conceptual models of complex systems can be useful management tools if they identify the critical components of the ecosystem and demonstrate the important, and often hidden, linkages between these components. Over the past decade scientists have come to appreciate that ecosystems seem to be organized in a hierarchical fashion. Each successively higher level of organization appears to operate at rates which cycle on longer time periods. Some systems appear to be able to constrain the activity of lower levels. Some systems are nested within other systems (Allen and Starr, 1982; O'Neill et al., 1986). Identification of these constraint mechanisms is very important because any action or event which can disrupt a constraint may result in instability of the system. Environmental managers must take care to avoid or minimize any perturbation that will disturb the natural constraints of the estuarine ecosystem. These constraints have proven difficult to establish and identify. Taylor and Blum (1991) caution that the use of graphics facilitates the ability to <u>act</u> as if ecological relations are decomposable into systems and manageable by analysts external to the system but this may be an illusion.

The goal of this project was development of a set of habitat-based, problem-oriented, nested, hierarchical, box-and-arrow conceptual models sensitive to spatial and temporal scales and tiered to three levels of complexity:

1) simple, non-technical models that will facilitate understanding of important issues by the public (see II. Overview of the Ecosystem);

2) complex, detailed models that reflect scientific consensus regarding ecosystem structure and function (see III. Components of the Estuarine Ecosystem); and

3) simple, technical models that will be useful to decision-makers, resource managers, and bay users (see IV. Interconnectedness of the Ecosystem).

The number of living species which inhabit Galveston Bay and its surrounding wetlands is known only to an order of magnitude; certainly more than 500 species (199 species of fishes alone), perhaps less than 1000 species. The conspicuous species - large plants, vertebrates, large invertebrates - are easily identified. As one descends the size scale into the microscopic range, less and less is known about relationships between successively smaller organisms in their natural environment. Phytoplankton are poorly understood, while bacteria, fungi, and viruses are hardly known at all. In theory, each species occupies a unique ecological niche. Any attempt to understand the interconnections between all of these species quickly boggles the mind and overwhelms our mental capacity. We need to simplify the ecosystem even to begin to study it.

Ecologists have traditionally envisioned the system from two viewpoints. Those scientists most interested in species have emphasized populations, guilds, and communities. By dealing with tangible entities and their aggregates, these ecologists have learned much about the structure of ecosystems. Other scientists have been fascinated by processes and functional phenomena, such as energy transfer, nutrient cycling and productivity. While the concept of trophic levels facilitates understanding of energy transfer and nutrient cycling, it often proves very difficult to assign a given species to a single trophic level. Many, perhaps most, species range broadly across trophic levels at different ages and developmental stages of their life cycle. Trophic level may be a non-entity (Scheiner et al., 1993). Descriptions of structure and function may not meld together neatly, even though they represent different observations of the same underlying ecosystem.

To complicate the issue, functional redundancy has been commonly observed. Many species can perform essentially the same ecosystem task. This implies that an ecosystem does not require a unique set of species at a particular point in space and time. The ecosystem persists while its components may vary, as long as appropriate functional interactions persist. Thus desirable species, from the human point of view, can be replaced by less desirable or undesirable species as environmental conditions change. If the conditions persist, a slightly different ecosystem may prevail. This ability to fluctuate confounds our attempts to understand ecosystems.

The multitude of available species and their functional redundancy and variability result in a paradox. A common suite of species appears to be widely available for the length of the Gulf coast. Indeed, many of these species, or closely related and functionally equivalent congeners, are distributed south to Yucatan or beyond, and north along the Atlantic coast. Yet each estuary appears to be a unique ecosystem. Matagorda Bay or the Sabine estuary are quite distinct from Galveston Bay, and these three are quite different from the estuaries of Louisiana, Mississippi, Alabama, or Florida. The same suite of species respond to unique environmental conditions to produce a different ecosystem in each estuary. It cannot be assumed that a structural or functional phenomenon studied in one estuary will be exactly replicated in another estuary, even when the species involved are the same.

To understand the complex interactions between structural and functional ecosystem components a conceptual model should be constructed. This model will be an abstraction of reality, but it should preserve important aspects of the real system. Ideally, the coupled model described will consist of several sub-components, each representing a small facet of the ecosystem. The coupled model may then be used to understand how the sub-components interface with one another, and the response of the entire system to large scale disturbances.

The GBNEP Scientific/Technical Advisory Committee conceptual model subcommittee hoped that these conceptual models would be useful for the following management tasks:

1. Demonstrate the diverse habitat types, their susceptibility to climatically-based physical forcing, and the complex history of anthropogenic perturbations to the estuary.

2. Provide an "ecological manual" for the estuary that will simplify the real ecosystem while preserving essential features, and improve communication between decision-makers, advisors, and the public.

3. Summarize the different management objectives of various agencies, and guide management and regulatory decisions to assure they are not at cross-purposes.

4. Assist in the development of appropriate segmentation schemes; monitoring programs; assessment of cumulative impacts; qualitative and semi-quantitative models; and predictive, quantitative, computer-based models which may be needed to meet program goals.

5. Aid in matching the scale of a problem (perturbation) to the scale of processes that result in altered ecological structure and rate of outputs, and determining the appropriate level of biological and ecological aggregation in addressing a specific environmental problem.

6. Codify scientific knowledge and theoretical constructs regarding the estuary to achieve scientific consensus, improve communication, and transfer this knowledge to other users of the bay.

The extent which the models developed herein will contribute to these ambitious goals will be determined in the future. It is difficult to describe the structure and function of a complex ecosystem without resorting to technical terminology. A glossary has been provided to facilitate understanding.